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SEISMIC PERFORMANCE OF A REINFORCED CONCRETE MULTI-STOREY BUILDING HAVING CIRCULAR SHEAR WALL AND SQUARE SHEAR WALL AT CORE OF THE BUILDING

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ABSTRACT

The shear walls and core walls are frequently used horizontal load opposing components in mid-rise to high-rise reinforced concrete buildings. The Placing of these walls plays an essential part in structural performance against horizontal loads. By engineering point of view, minimum movement and high absorbent of energy are specified as a critical reason to decide shape and place of shear walls. Round sections are safer contrasted with square sections, because the execution of round section is same in all directions but square portions are intended for two principal headings against seismic loads and their execution is not clear in different directions. The present study focuses on the evaluation of the seismic execution of reinforced concrete buildings with circular core wall and square core wall according to Indian Codes (IS 1893:2002). For this analysis, five square building with 20 stories having circular core wall and rectangular core wall and one circular building with 20 stories having circular core wall is considered. By response spectrum and time history analysis the dynamic behavior of the structure has been found. All the analysis was performed in ETABS software, from the analysis results a study of storey deflection, storey drift and base shear have been made.

Key words: shear wall, Response spectrum analysis, Time history analysis, ETABS.

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1. INTRODUCTION

The primary purpose of different types of structural system in buildings is to resist gravity loads like dead, live loads. Besides these vertical loads, lateral loads caused by wind, earthquake also acts on buildings [4]. It is very important that structure should resist both vertical loads and lateral loads. The shear wall-frame system is the most commonly used structural system in reinforced concrete buildings to counteract the effect of both gravity and horizontal loads. These shear wall-frame system have high lateral resistance against horizontal loads by placing shear walls in an advantageous location in the plan of building.

1.1. Shear Wall

Shear walls are vertical reinforced concrete structural elements to resist both gravity and lateral loads acting on the structure. The thickness of wall varies from 200 to 500mm, depends on the height of the building and seismic zone of building area. They are different types of shear walls in building system 1) simple rectangular type and flanged walls 2) coupled shear wall 3) core type shear wall.

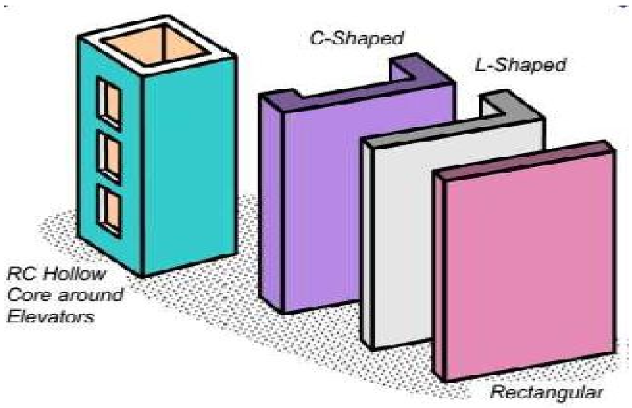

Figure 1 Types of shear walls

The simple rectangular wall is generally placed between periphery columns of building and core walls are placed around the staircase and elevator to resist the vibration loads and lateral loads. In the present study, both simple rectangular wall and core wall are included in the building frame. In order to counteract the torsional effect, the center of resistance of the building should coincide with the center of mass of building [12].

Normally the civil engineering structures are designed within the elastic range, but under a strong seismic event, a structure may really be subjected to forces past its flexible breaking point. In spite of the fact that construction laws can give a dependable sign of real execution of individual structural components, it is out of their extension to depict the normal execution of planned structure as a whole, under huge forces. A few businesses, for example, car and flight, routinely construct full-scale models and perform broad testing, before assembling a large number of indistinguishable structures, that have been examined and composed with the thought of test outcomes. Unfortunately, this choice is not accessible to building industry as because of the uniqueness of normal individual structures, the economy of substantial scale creation is unachievable [11].

With the accessibility of quick PCs, performance-based seismic engineering(PBSE), where inelastic analysis of structures is joined with seismic evaluation to compute seismic execution of a structure with the assistance of this instrument, structural engineers as well, in spite of the fact that on a PC and not in a lab, can watch expected execution of any structure

under expansive powers and change outline appropriately. Nonlinear time history analysis is a conceivable technique to calculate the response of the structure under earthquake forces. However, because of the substantial measure of information produced in such examination, it is not viewed as pragmatic and PBSE, as a rule, includes nonlinear static investigation, otherwise called pushover analysis. The present study includes the response spectrum analysis and time history analysis, by this analysis, the dynamic behavior of the structure can be found.

2. RELATED WORKS

In the current past, significant research has been done on the seismic reaction of RCC structures with shear walls.

Azzam Katkhoda and Rana Knaa (2012) investigated on the optimization in the selection of a structural system for the reinforced concrete buildings to resist earthquake forces. Three types of structural systems (frame system, shear wall system, and couple system) consider for the study, ETABS software is used to model and analyze the structure. From the analysis results, he found that coupled system having core walls and shear walls is giving good results [4].

Mohamed A. dahesh and tuken (2015) evaluated the effect of the shear wall in RC building to control the lateral displacement caused by the earthquake. For this study, they modeled square building in STADD.PRO software. The results have been carried for the parameters including the area of the shear wall, shear wall height, and openings in the shear wall. From the analysis outcome, he found that increasing area of shear wall to area of floor ratio from 0.56 to 1.29% decreases the displacement by 38 to 72% [5].

Manuchehr Behruyan and Mehdi Mohammadi (2014) conducted a study to compare the performance of circular core shear wall to conventional shear wall. Different types of building models with the circular shear wall at the core and square shear wall at the core are analyzed to find out the relative movement of the structure. From the analytical results, he found that relative movement of circular core building is decreased 27% compared to square core building [6].

Mahdi Hosseini and N.V .Rama Rao (2015) conducted a study to find the seismic performance of a building with the shear wall at core and center of the outer frame. For this study, a forty storey RC building is modeled and analyzed in ETABS Software. From the results, he found that building with core wall and external shear wall shows better performance in terms of lateral displacement and storey drift. Also, the stress concentration in shear wall increases when the opening is provided [9].

3. METHODOLOGY OF PROPOSED WORK

1) Modeling of the twenty storey buildings with core wall and shear wall at exterior frames with openings in ETABS

2) Application of gravity loads (dead, live, wall load, floor finisher) as per Indian codes and lateral loads as per IS 1893:2002

3) Analyzing the building using Response spectrum analysis, time history analysis.

4) Comparing the results of building models.

There is a different method of seismic analysis which gives distinctive degrees of accuracy. The analysis process can be a group on the premise of three variables: the kind of the externally applied loads, the behavior of structure materials, and the sort of structural model chosen. Based on the type of external action and structural behavior, the analysis can be classified as linear static analysis, linear dynamic analysis, non-linear static analysis,

nonlinear dynamic analysis. Linear static analysis or equivalent static analysis are applicable to the regular structure with a height limit. Under linear dynamic analysis, there are two types of analysis, they are response spectrum method and elastic time history method. Nonlinear static analysis or pushover analysis allows the inelastic behavior of structure [3].

3.1. Equivalent Static Analysis

Earthquake analysis of the majority of the structures is still done in the light of the presumption that horizontal load is equal to actual loading. The base shear which is the aggregate horizontal force on the structure is calculated based on the mass of the structure and fundamental period of vibration and relating mode shape [3]. The base shear is applied along the height of the structure in terms of horizontal forces according to code formula. This method is applicable to buildings of low to medium height with the regular plan.

3.2. Response Spectrum Analysis

Earthquake engineers preferred to report an interaction between the acceleration of ground and structural system through response spectrum first proposed by Biot and later popularized by Housner. A Response spectrum is a plot of the maximum response of a set of SDOF systems subjected to ground motion as ordinate and corresponding time periods of the SDOF system as abscissa. This method is applicable for those structures where modes other than the basic mode that influences the structure reaction. In this method the Multi-degree-of-Freedom (MDOF) system response is expressed as the superposition of modal response, by the spectral analysis of single-degree-of-freedom (SDOF) system, the response of the each mode being determined, which are then combined to find out the total response [13].

Methods of combining modal response:

- Absolute – peak values are added together
- Square root of the sum of the squares (SRSS)
- Complete quadratic combination (CQC)

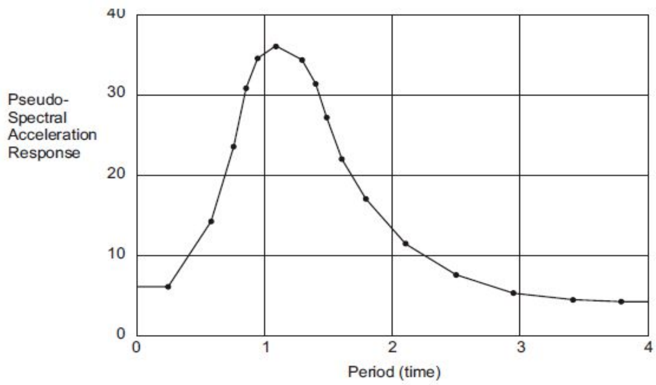

Figure 2 response spectrum curve

3.3. Time History Analysis

Time history analysis provides a linear or non-linear dynamic response of the structure under loading which varies with the time function. In this analysis method, a selected earthquake time history data is applied directly to the structure [8]. Dynamic seismic loads influence the structure with time intervals. For present study EL CENTRO (1940) earthquake time history data with site source distance of 8km has been considered.

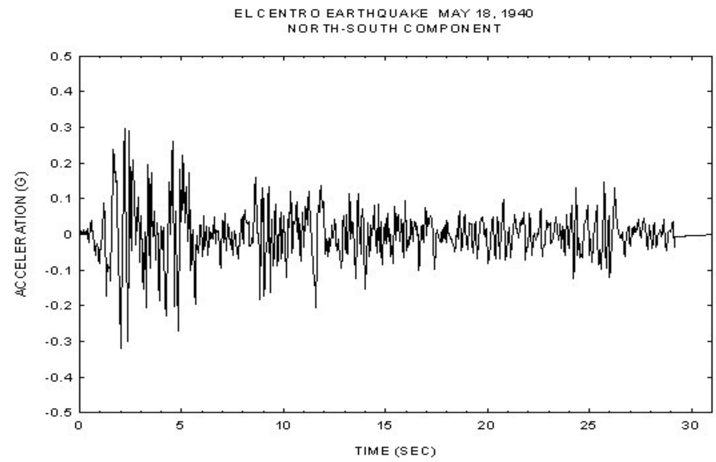

Figure 3 ELCENTRO time history data

There are two methods to perform time history analysis, they are direct integration method and fast non-linear analysis (FNA) method, for the present study fast non-linear analysis (FNA) method is adopted.

4. MODELLING

In this study, six models are considered to perform the seismic analysis. All the models having 20 stories and height of each storey was 3m. First five models are in the square plan of 20m x 20m with 5 bays on each side and the sixth model is circular in plan having a diameter of 20m. In all the models the lateral loads are resisted by shear walls at exterior frames and core walls at the center of the building. The sizes of the openings in shear wall are 1.5m x 2m for doors and 1m x 1.5m for windows

4.1. Material Properties

Table 1 Material Properties

Material properties	values
Grade of concrete	M25
Grade of steel	FE415
Young's modulus of steel	200000MPa
Young's modulus of concrete	25000MPa

4.2. Section Properties

Table 2 Section Properties

Size of beam	230mm x 450 mm
Size of rectangle column	230mm x 530 mm
Size of circular column	500mm
Thickness of slab	150mm
Thickness of masonry wall	230mm
Thickness of shear wall	250mm

4.3. Loads on Building

Table 3 Loads on Building

Live load	$2kn/m^2$
Floor finisher	$1kn/m^2$
Wall load	12kn/m
Seismic zone	v
Soil type	2
Importance factor	1
Response reduction factor	5
Damping percentage	5%

4.4. Building Models

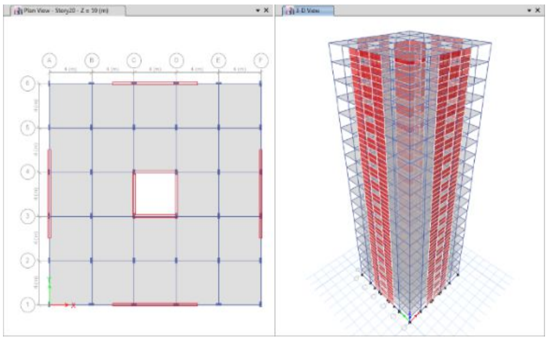

Figure 4 Model 1 (building with square Core wall and shear wall at the center of the Exterior frames)

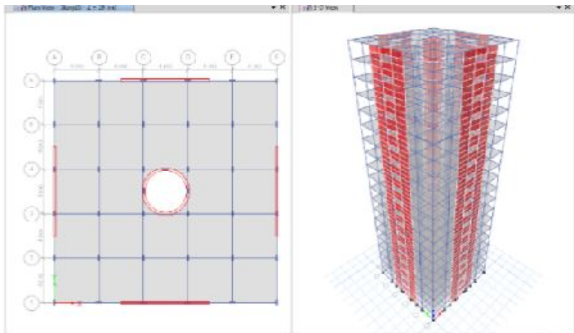

Figure 5 Model 2 (building with circular core wall and shear wall at the center of the exterior frames)

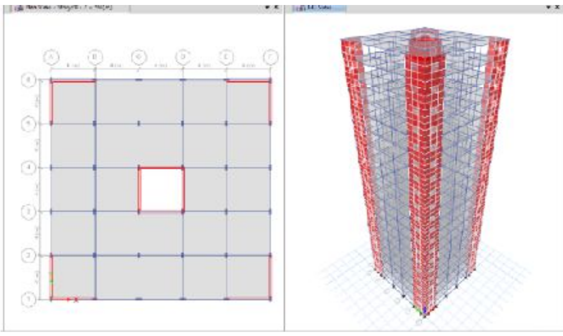

Figure 6 Model 3 (building with square Core wall and shear wall at each corner of Exterior frames)

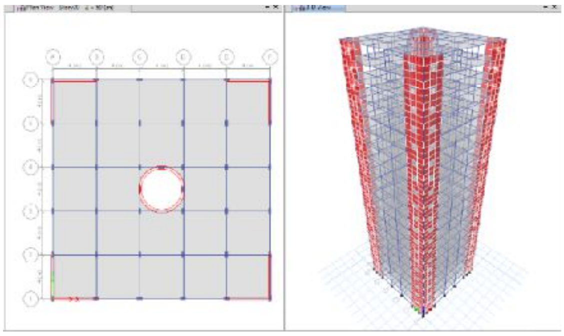

Figure 7 Model 3 (building with circular core wall and shear wall at each corner of exterior frames)

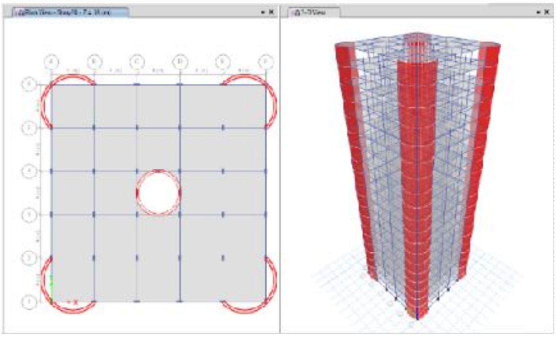

Figure 8 Model 5 (building with circular Core wall and curved shear wall at each Corner of the building)

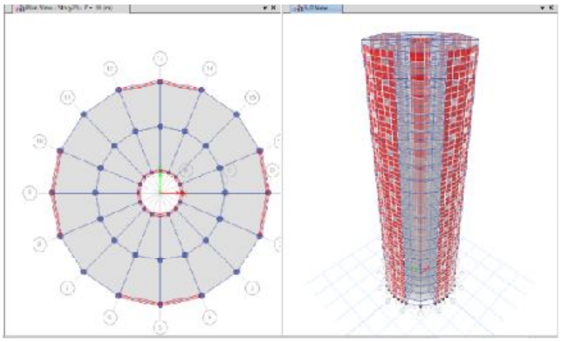

Figure 9 Model 6 (circular building with circular core wall and rectangular shear wall

5. RESULTS AND DISCUSSIONS

All the models are analyzed for both response spectrum and time history analysis in ETABS Software. From the analysis results a comparative study made on storey displacement, storey drift, base shear and time period.

5.1. Response Spectrum Results

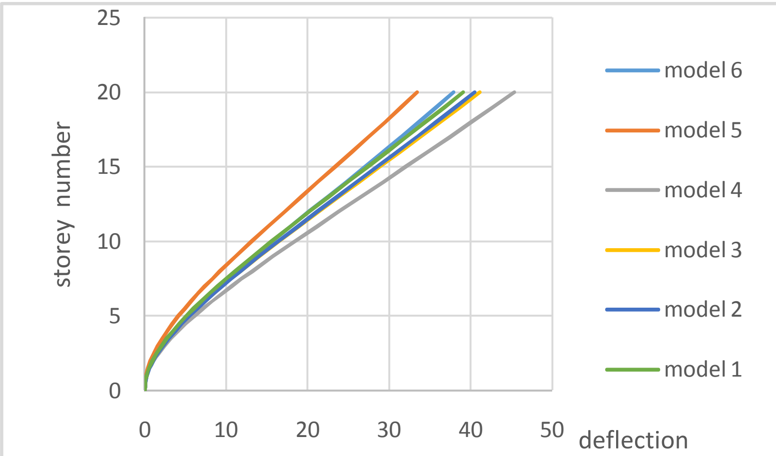

Figure 10 Displacement in x-direction

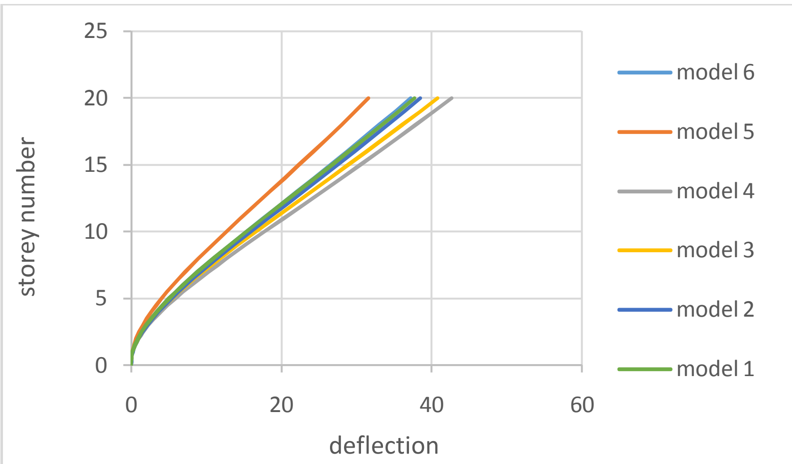

Figure 11 Displacements in y-direction

Table 4 maximum storey displacement in x-direction and y-direction

storey	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	x-axis	y-axis	x-axis	y-axis	x-axis	y-axis	x-axis	y-axis	x-axis	y-axis	x-axis	y-axis
20	39.0	37.7	40.4	38.5	41.0	40.8	45.3	42.6	33.4	31.6	37.8	37.2
19	36.7	35.6	38.1	36.3	38.6	38.4	42.6	40.3	31.4	29.8	35.7	35.1
18	34.4	33.4	35.7	34.2	36.2	36.1	40.0	37.9	29.4	28.0	33.6	33.0
17	32.1	31.2	33.3	31.9	33.7	33.7	37.3	35.4	27.4	26.1	31.4	30.9
16	29.7	29.0	30.9	29.7	31.2	31.3	34.6	33.0	25.4	24.2	29.2	28.7
15	27.3	26.7	28.5	27.4	28.7	28.9	31.9	30.5	23.3	22.3	27.0	26.5
14	24.9	24.4	26.0	25.1	26.2	26.4	29.2	27.9	21.8	20.4	24.7	24.3
13	22.5	22.1	23.6	22.8	23.8	23.9	26.5	25.4	19.2	18.4	22.4	22.0
12	20.1	19.9	21.1	20.5	21.3	21.5	23.7	22.8	17.1	16.5	20.1	19.8
11	17.8	17.6	18.7	18.2	18.8	19.0	21.0	20.2	15.1	14.6	17.8	17.5
10	15.5	15.3	16.3	15.9	16.4	16.6	18.3	17.7	13.1	12.6	15.6	15.3
9	13.2	13.1	14.0	13.6	14.0	14.1	15.7	15.2	11.1	10.8	13.3	13.1
8	11.0	10.9	11.7	11.4	11.6	11.8	13.1	12.7	9.22	8.96	11.1	10.9
7	8.9	8.88	9.51	9.29	9.43	9.57	10.6	10.3	7.40	7.21	9.05	8.88
6	6.9	6.91	7.42	7.25	7.31	7.41	8.27	8.00	5.70	5.56	7.05	6.90
5	5.1	5.07	5.48	5.35	5.35	5.42	6.06	5.86	4.14	4.04	5.19	5.07
4	3.4	3.43	3.73	3.63	3.60	3.63	4.08	3.93	2.76	2.69	3.52	3.43
3	2.0	2.03	2.22	2.16	2.11	2.12	2.39	2.29	1.60	1.56	2.10	2.03
2	0.9	0.92	1.03	0.99	0.96	0.95	1.07	1.01	0.70	0.69	0.98	0.94
1	0.2	0.2	0.23	0.22	0.20	0.2	0.22	0.20	0.14	0.15	0.23	0.22
0	0	0	0	0	0	0	0	0	0	0	0	0

Figure.10 and figure.11 shows the comparison of maximum storey displacements for all six models in x-direction loading and y-direction loading. Table.4 shows the maximum displacement values along both the x and y directions. From the figures 10 and 11, we can observe that model 5 (building with circular core wall and semi-circle shear walls at corners) subjected to less displacement compared to other models. Model 4 (building with circular core wall and rectangle shear wall at corners) subjected to a large displacement. The least displacement value in model 5 is 33.43mm in x-direction and 31.62mm in the y-direction. The large displacement value in mode 4 is 45.30mm and 42.697 in x and y directions. The displacement values of all the models are within the limitation of codal provision i.e. 5% of the height of the building.

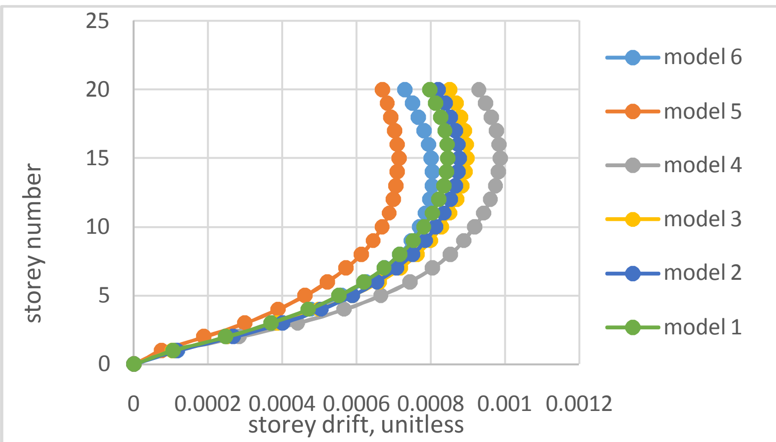

Figure 12 Storey drift in x-direction

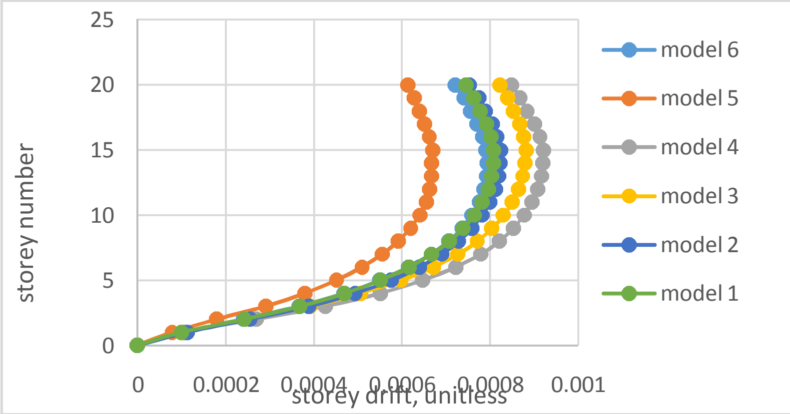

Figure 13 Storey drift in y-direction

Figure 12 and 13 shows the comparison of max storey drift in Directions x-direction and y-direction. From the figure, we can observe that model 5 shows the least drift compare to other models and model 4 shows the large drift value in both x and y –directions. The max drift values of model 5 have occurred between 14th and 15thstorey i.e. 0.000669 in the x-direction and 0.000715 in the y-direction. The max drift value in model 4 in the x-direction is 0.000987 and in the y-direction is 0.00095 occurred in between 14 and 15 storey. The allowable drift value is 0.004 time the height of the structure, therefore the max drift allowed is 0.004x3 = 0.012. In all the models the drift values are less than the maximum drift value.

Table 5 Base Shear Values

	Base shear	
	x-direction	**y-direction**
Model 1	3029.436	3206.761
Model 2	2862.674	3049.235
Model 3	2640.061	2797.872
Model 4	2502.944	2645.850
Model 5	1835.931	1928.773
Model 6	3080.596	3049.694

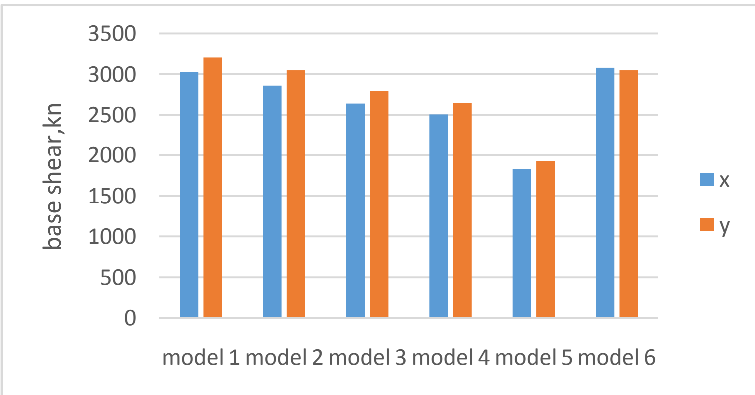

Figure 14 base shear value of models in x and y-directions

Figure 14 shows the comparison of base shear values of models for both x-direction and y-direction loading. The base shear values are shown in table 5. From the figure 14 model 4 having less base shear in both x and y-directions compare to other models i.e. 2502.944kn and 2645.850kn and model 1 has high base shear in y-direction i.e. 3206.761kn. The base

shear value depends on the seismic weight of the building and time period of the structure. Having low base shear value indicates that the structure is flexible and high base shear indicates that the structure is stiff. For flexible structure the natural frequency is high and for stiff structure, the natural frequency is less.

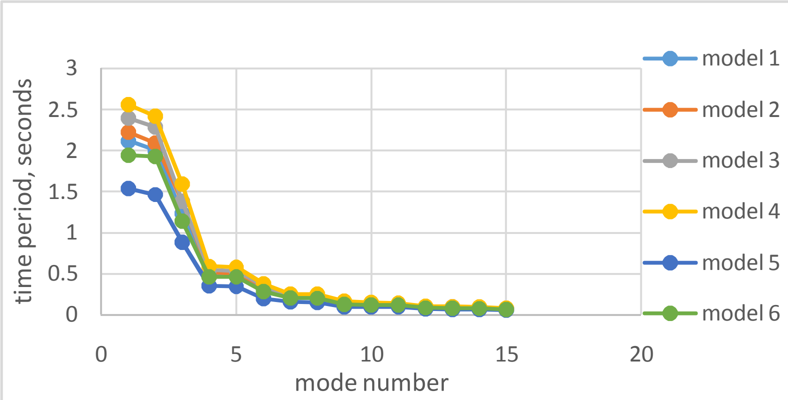

Figure 15 time periods

For each model 15 modes are considered to satisfy the modal mass ratio of the structure. From the figure 15 we can observe that model 5 having less time period i.e. 1.563 seconds for the first mode and 0.058 seconds for the 15thmode, therefore the model 5 is stiffer against lateral loads compare to other models. Model 4 having large time period i.e. 2.561 seconds at 1st mode and 0.076 at 15th mode which represents the structure is flexible.

5.2. Time History Results

From time history analysis the response of the structure is studied by applying ELCENTRO time history data with peak acceleration value as 0.34g. The storey displacement, storeyDrift, base shear and time period values are presented in this study. The Seismic load is applied in each orthogonal direction separately. For the analysis 200 output time steps are consider and output time step size 0.1seconds.

Figure 16 and 17 shows the graphical representation of storey deflection in x and y-directions. From the above graphs, we can observe that model 5 subjected to less deflection compared to other models and model 4 subjected to a large displacement. The displacement value of model 5 are 17.474mm and 16.508mm and for model 4 is 35.157mm and 31.554mm which is 2 times higher than the model 5. The above values represent that model 5 is showing the best performance. Displacement values of all models are in the limit of codal provision i.e. 5% of the height of the structure.

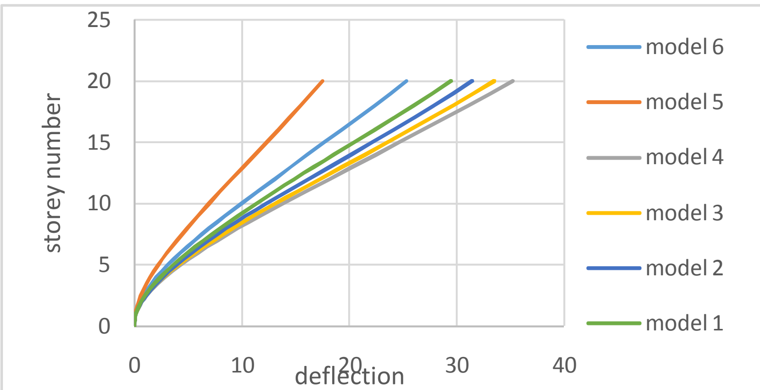

Figure 16 Deflection in x-direction

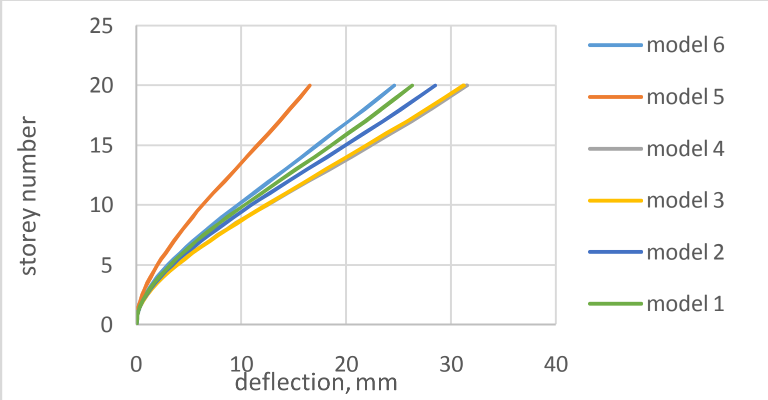

Figure 17 Deflection in y-direction

Figure 18 and 19 shows the graphical representation of the storey drift in both x and y-directions. From the figures 18 and 19 we can observe that model 4 having less drift ratio i.e. 0.000379 and 0.000354 in both directions comparing to other models and model 4 having high drift ratio i.e. 0.000753 and 0.000671 in both directions. The maximum drift allowed is 0.004 times the storey height i.e. 0.004x3m = 0.0012mm, therefore all models having drift values less than allowable drift.

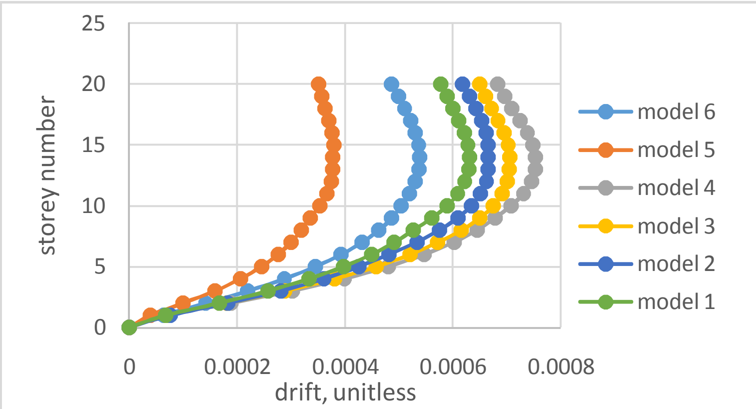

Figure 18 Storey drift in x-direction

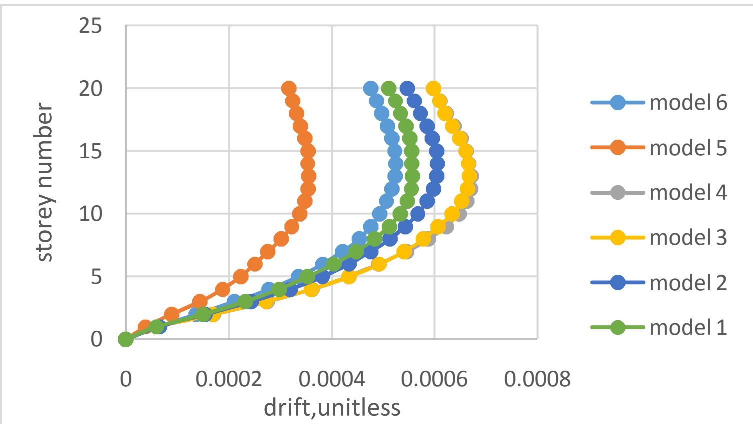

Figure 19 Storey drift in y-direction

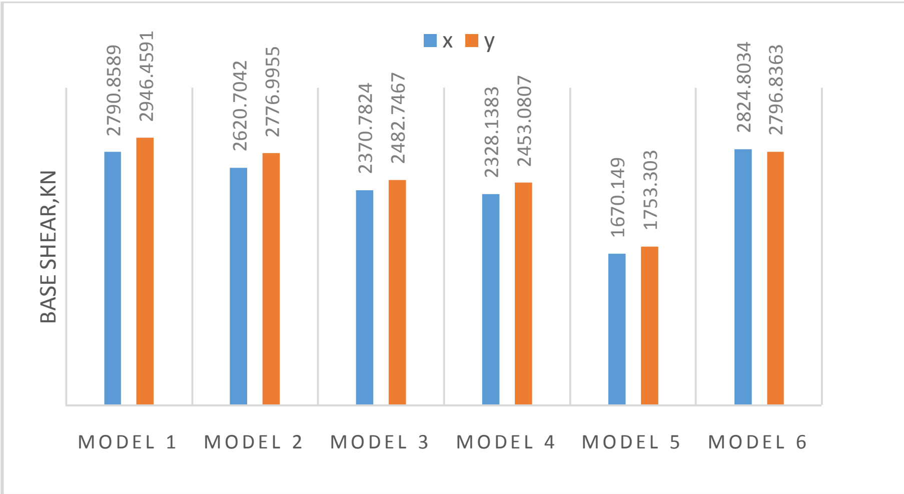

Figure 20 Base Shear values in x-direction and y-direction

Base shear values are shown in figure 20. From the figure we can observe that model 5 is having less base shear compare to other models and model 1 is having high base shear which represents that model 5 is stiffer and model 1 is flexible compared to other models.

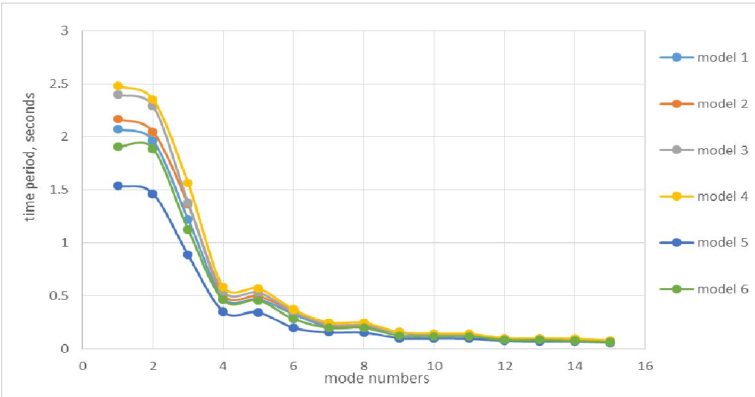

Figure 21 Time Period values of all models

Figure 21 shows the graphical representation of the time periods for all models. Model 5 having less time period which represents stiff structure and model 4 having low time period which represents that the structure is flexible compared to other models.

Table 6 Maximum Acceleration values for all models

	Maximum acceleration values
Modal 1	457.33 mm/s^2 occurs at 11.7 seconds
Modal 2	458.40 mm/s^2 occurs at 11.7 seconds
Modal 3	383.30 mm/s^2 occurs at 11.7 seconds
Modal 4	581.04 mm/s^2 occurs at 11.6 seconds
Modal 5	755.15 mm/s^2 occurs at 11.6 seconds
Modal 6	509.71 mm/s^2 occurs at 11.7 seconds

From table 6 we can observe that model 5 having more acceleration value which represents the structure is rigid and model 3 showing less acceleration value which represents the structure is flexible.

6. CONCLUSION

The proposed study has been done on reinforced concrete multi-storey building with the shear wall at the center of the building and at exterior frames of building. Response spectrum analysis and time history analysis has been performed on the structure, for time history analysis ELCENTRO earthquake time history data is considered to perform the analysis. The impact of shear wall location and shape of shear wall on the seismic performance of the created models has been studied. From the results presented above the following conclusion are made.

In terms of displacement results the building with circular core shear wall and semi-circular shear walls at corners of the building subjected to low displacement compared to other models presented above from both response spectrum analysis and time history analysis. In terms of storey drift also model 5 (building with the circular shear wall at the core and semi-circular shear wall at corners) having less drift value compare to other models. The Natural time period of the building is less for model 5 i.e. 1.536 seconds from both the analysis which represents that model 5 is having high stiffness.

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